

26
Fish. Bull
HOWARD H. ECKLES
WILLIAM H. ROSE
#26
DIVISION OF FISH AND GAME OF CALIFORNIA

FISH BULLETIN No. 26

Seasonal Changes in the Daily Average
Length of the California Sardine
Sardina caerulea

LIBRARY
BUREAU OF COMMERCIAL FISHERIES
U. S. FISH AND WILDLIFE SERVICE
P. O. BOX 3830

HONOLULU 12, HAWAII
By
FRANCES N. CLARK

Contribution No. 100 from the California State Fisheries Laboratory,
January, 1930



CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO, 1930

DIVISION OF FISH AND GAME OF CALIFORNIA

FISH BULLETIN No. 26

Seasonal Changes in the Daily Average
Length of the California Sardine
Sardina caerulea

By
FRANCES N. CLARK

Contribution No. 100 from the California State Fisheries Laboratory,
January, 1930



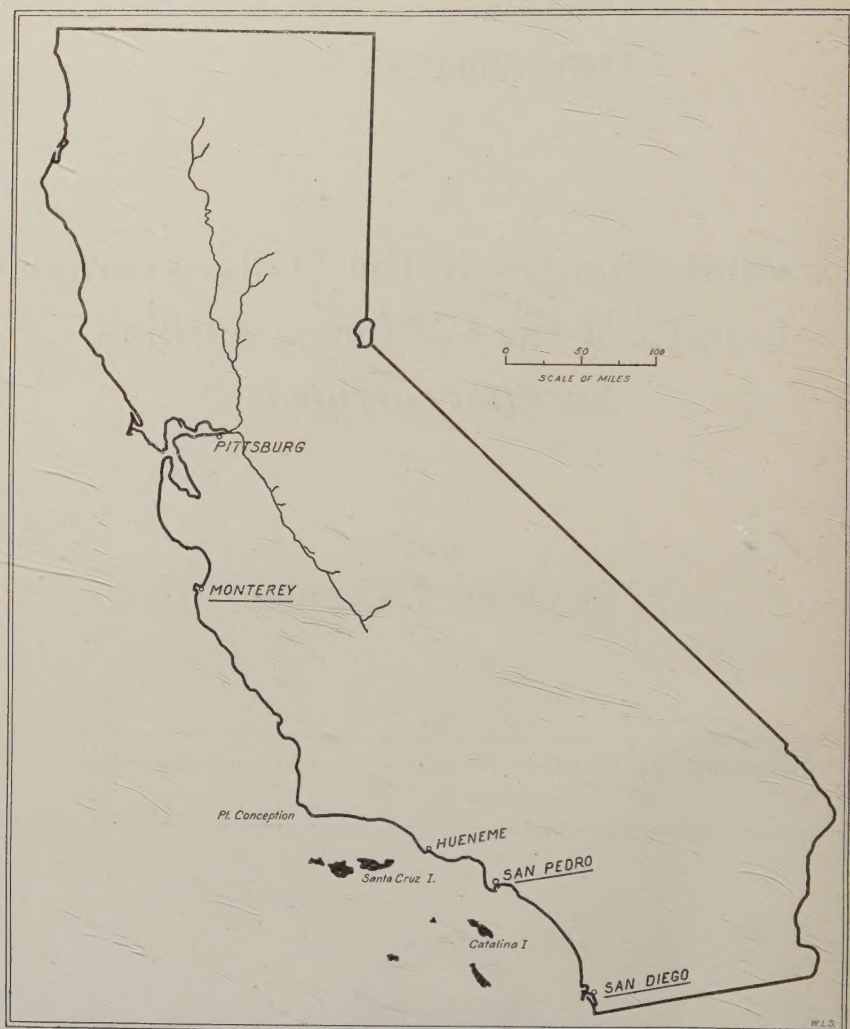


FIG. 1. Outline map of California to show the location of the sardine canning sites of the state. The three names underlined are the most important in the sardine industry. (From Fishing Areas Along the California Coast for the Sardine (*Sardina caerulea*). California Division of Fish and Game, Fish Bulletin No. 25, Fig. 1.)

ACKNOWLEDGMENT

The assistance rendered by past and present members of the staff of the California State Fisheries Laboratory in the collection of the material used in this study and in the helpful suggestions offered during the analysis of the data is gratefully acknowledged. Mr. W. L. Scofield, in charge of the laboratory, and Dr. W. F. Thompson, Director of Investigations for the International Fisheries Commission—United States and Canada, aided much in the revision of the manuscript. The graphs were drawn by Miss Annie Gillespie.

The changes in daily average lengths within a fishing season, resulting from the movements of the fish, were reflected in the industry. In the fall months when small fish were present in the fishing areas more sardines were packed in a can than during the winter months, when larger fish were found on the fishing grounds.

Collection and Treatment of the Data.

During the past ten years, 1919-1929, the California State Fisheries Laboratory has collected material for population studies on the California sardine at the two major fishing ports, Monterey and San Pedro. For the years 1928 and 1929 similar data have been gathered at San Diego. The method of making these collections was described by Scofield (1926.1) and Higgins (1926) and need not be discussed in detail again. Briefly, the procedure was as follows: During the 1919-1920 and the 1920-1921 seasons at San Pedro, and from 1919 to 1923 at Monterey, samples of sardines were taken from five fishing boats daily, and in the following years samples were taken from five boats semiweekly. The adequacy of semiweekly sampling was demonstrated by Sette (1926). At San Pedro each sample consisted of 50 fish and at Monterey of 40 fish, making a total of 250 fish and 200 fish

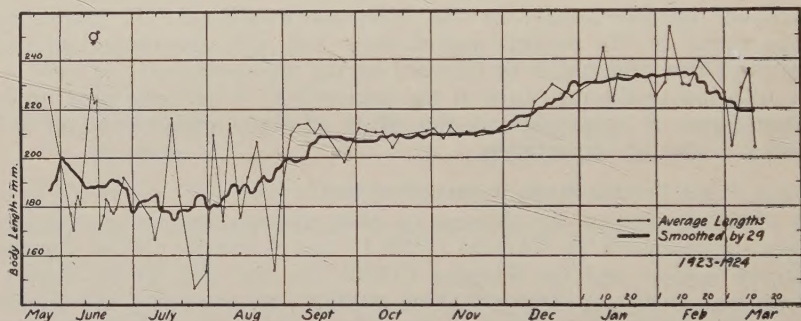


FIG. 2. Graph to show the effect of smoothing upon the average length data. [From Andrews, Carroll B. Seasonal Average Length Trends at Monterey of the California Sardine (*Sardina caerulea*). California Division of Fish and Game, Fish Bulletin No. 13, fig. 1.]

measured in one sampling day. A method of sampling similar to that used at San Pedro, has been carried on at San Diego during 1927-1928 and 1928-1929.

Each fish was measured on a measuring board and measurements read to the nearest millimeter. The standard length used in all the sardine studies is from the tip of the mandible to the end of the silvery area exposed on the caudal peduncle when the scales are removed. This is termed body length. The daily average body length was calculated by dividing the sum of the lengths of all fish measured on one day by the total number of fish. Sexual differences in length were not considered and all calculations were based on a combination of males and females.

The daily average lengths showed many minor variations over short periods of time, but these minor variations were eliminated to demonstrate clearly the major changes within a fishing season. This was accomplished by smoothing the daily average lengths by a moving average of 29 calendar days. Other methods of eliminating minor variations to clarify the trend of average lengths throughout a season

were not found as satisfactory as smoothing by 29 calendar days. Biweekly combinations did not eliminate all the small irregularities, nor did smoothing over any time interval smaller than 29 days. The effect on the data of this method is shown in figure 2 which has been taken from Andrews (1928).

California sardines are caught almost exclusively at night when the schools of fish are located by the luminescent light resulting from the movements of the fish. For about five to ten days during the full of the moon, fishing is practically discontinued because the nights are too light for the fishermen to see the schools of fish. Because the continuity of the sampling is thus periodically interrupted, and since, as indicated by Scofield (1926.1), the daily average size of sardines fluctuates within a lunar month, smoothing by 29 days was necessary to provide a sufficiently large time interval to span this break in the sampling series and to eliminate lunar-month variations in size. Although daily and weekly changes in the average size of sardines are of significance in studies covering short time intervals, this discussion deals only with the changes occurring throughout an entire fishing season and the above rather severe method of smoothing the trends is consequently the most satisfactory.

To obtain five- and ten-season average length trends, the smoothed data for corresponding calendar days of each season were summed and each of these sums divided by the number of seasons involved.

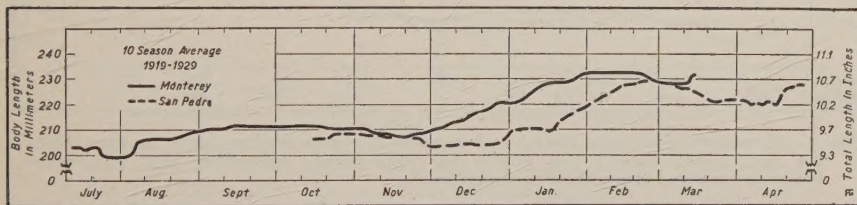


FIG. 3. Ten-season average trend of daily average lengths of San Pedro sardines compared with the ten-season average trend for Monterey sardines.

COMPARISON OF THE DAILY AVERAGE LENGTH TRENDS FOR MONTEREY AND SAN PEDRO

Ten-season Average Trends.

The clearest conception of the general changes in daily average lengths which occur within a fishing season is obtained from the ten-season average trend of the daily average lengths. These trends for Monterey and for San Pedro are shown in figure 3. The contrast between the dates of the fishing seasons at the two ports is clearly indicated. During the ten seasons studied, 1919-1929, fishing at Monterey began in July or August and continued until mid-March, while at San Pedro fishing began between October and December and continued through April and occasionally into May. This difference in the time of capture of sardines in the two localities has been pointed out by Scofield (1928). In 1929, the California legislature restricted the time in which sardines can be taken for canning purposes and the season now opens at Monterey on August 1 and closes on February 15. At San Pedro the season extends from November 1 to March 31.

The two ten-season average trends for Monterey and San Pedro show that in both localities fish taken during the fall months, August to November or December, averaged about two centimeters smaller than did the sardines taken in the winter months. In January or February the daily average lengths attained a maximum size and decreased slightly at the close of the fishing season.

While in both localities the seasonal change in daily average length, from small fish in the fall through a transition period to large fish in the winter, was the same, the time of occurrence of this change differed by about a month. At Monterey small fish were taken from July to October; after the middle of November the average lengths increased steadily until a maximum was reached in the middle of January. This maximum was maintained until the latter part of February and then followed by a slight decrease at the end of the season. On the other hand, at San Pedro small fish were taken from October until the last of December or early January. The increase in size occurred from the middle of January to the middle of February and the maximum size was maintained from the latter part of February through early March. This was followed by a slight decrease toward the close of the season.

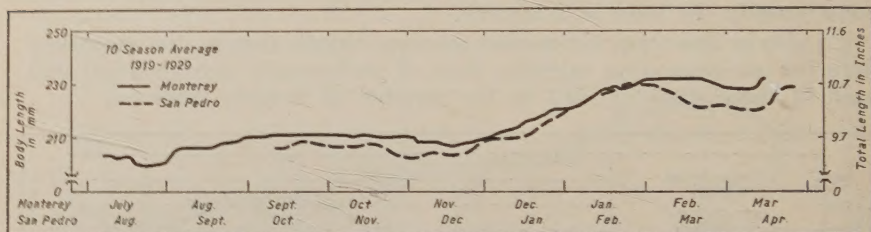


FIG. 4. Comparison of San Pedro and Monterey ten-season average trends. Data for San Pedro lagged one month to demonstrate consistent size differences between sardines from the two localities.

The difference in the time of the occurrence of the changes in average lengths in the two localities obscured certain average size differences between the two localities. To indicate these size differences more clearly, the ten-season average trends of daily average lengths are again shown in figure 4. In this figure the San Pedro data are lagged one month and January 1 at San Pedro coincides with December 1 at Monterey. Fish taken from September to November at Monterey averaged three or four millimeters greater than did fish taken from October to December at San Pedro. During the transition period the average length trends overlapped and the maximum size of the winter fish for the two localities was similar, although the Monterey maximum exceeded the San Pedro maximum by one or two millimeters. The maximum average size, however, was maintained over a longer period of time at Monterey than at San Pedro.

Five-season Average Trends.

Although the ten-season average trends of the daily average lengths indicate clearly the changes within a fishing season, from small to larger fish, which occurred at both localities and the variant dates when these changes took place, the sizes during the first half, 1919-1924, of the ten-season interval, differed from the second half, 1924-1929,

of the same interval. These differences are best shown in a comparison of average trends covering smaller time periods. This was accomplished by calculating five-season average trends for the first and for the second half of the ten-season period. The resulting trends for the two localities are shown in figure 5.

The trends for Monterey, in the upper graph of this figure, indicate that, with the possible exception of January, the average lengths during the second five-season period were greater than during the first five-season interval. This difference was very marked during the fall months, and although much less, was evident in February and early March. A similar increase in average size was demonstrated by Andrews (1928) for the Monterey data in a comparison of the four fishing seasons from 1919 to 1923 with the four seasons from 1923 to 1927.

The trends for San Pedro are shown in the lower half of figure 5. Since the fishing seasons during the first five years were much shorter than during the second five, the trends can be compared only for the

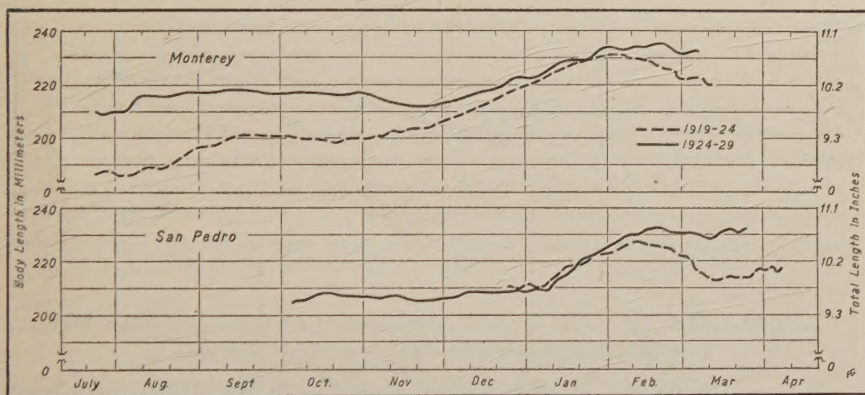


FIG. 5. Five-season average trend of the daily average lengths for 1919-1924 compared with five-season average trend for 1924-1929 for Monterey and for San Pedro.

latter half of the season. During January the average sizes for the two time intervals differed but little, while in February and March the average lengths were consistently greater in the second five-season period than in the first. This difference in average size during the winter months was equal to if not slightly greater than the differences in the Monterey data for the same time intervals. In both localities the maximum average size was maintained later into the spring in the 1924-1929 interval than in the 1919-1924 period.

To compare the 1919-1924 five-season average trend for Monterey with the same trend for San Pedro, and similarly the 1924-1929 five-season average trends for the two localities, figure 6 is given. As evinced by these trends, in general the seasonal fluctuations in the average length of sardines were similar in the two localities. At both San Pedro and Monterey, the average lengths were smaller in the fall months, increased to a maximum in the winter and decreased slightly in the spring. On the other hand, two differences are apparent. During the first five-season period the sardines at San Pedro did not attain

as great an average length as did the fish at Monterey. In the second five-season interval the maximum average length during the winter months was approximately the same in the two localities but the fall fish at Monterey were larger than the fall fish at San Pedro. This condition is similar to locality differences in the ten-season average trends. For the first five-year period, no fish were taken before December at San Pedro and a comparison with fall fish from Monterey can not be made. Also, as in the ten-season average trends, the transition from smaller to larger sizes occurred later in the season at San Pedro than at Monterey.

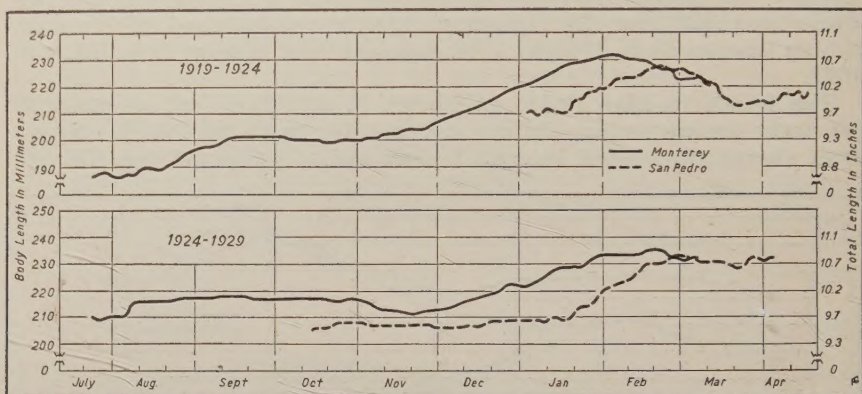


FIG. 6. Two five-season average trends of the daily average lengths of San Pedro sardines compared with similar trends for Monterey sardines.

COMPARISON OF THE DAILY AVERAGE LENGTH TRENDS FOR MONTEREY, SAN PEDRO AND SAN DIEGO

Data on the lengths of the California sardine at San Diego have been collected for two seasons only, 1927-1928 and 1928-1929. Sardine canning at San Diego differs from that at Monterey and San Pedro. At San Diego three types of sardines are packed, "quarter-oils," "halves," and "pound-ovals." The quarter-oils comprise small fish packed in one-fourth pound cans. The halves are larger than the quarter-oil sizes but smaller than the pound-ovals, and are packed in half-pound cans. The pound-oval sizes correspond roughly to the pound-ovals of the other two districts. Since this study is concerned with pound-oval fish only, the halves and quarter-oils have been omitted from the daily average lengths of San Diego sardines. To accomplish this, only fish exceeding 180 mm. in body length were included in the calculation of the average length on any specific day. The upper limit of the size range for halves falls at approximately 180 mm.

The seasonal daily average length trends at San Diego for the two seasons are shown in figure 7. The fishing season at San Diego for pound-ovals is briefer than at Monterey or San Pedro, comprising the months of January, February, March, and occasionally early April. Under present legislative restriction the season will close on March 31. The daily average length trends showed an increase through January and reached a maximum in February. In the 1929 season this maximum

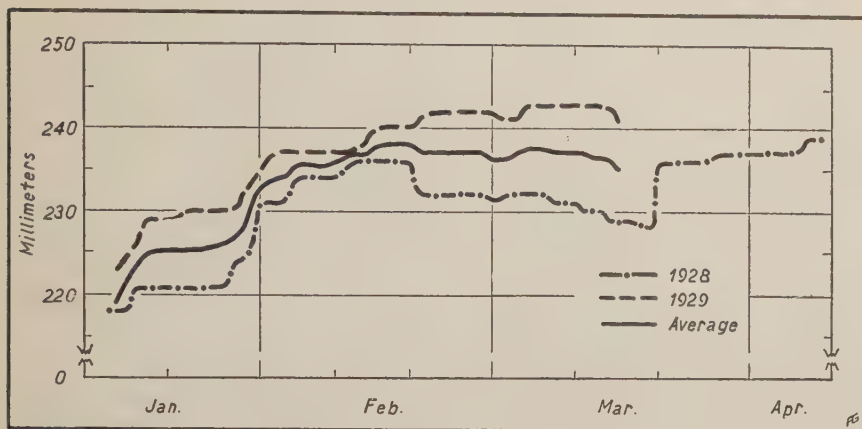


FIG. 7. Trends of the daily average lengths of San Diego sardines for two seasons, 1928 and 1929.

average was maintained throughout March, but in the previous season the averages decreased in late February and early March, rising again during the latter half of that month and early April.

To make the trends for the three regions comparable, the Monterey and San Pedro data were treated in the same manner as the San Diego data. Since a few of the pound-oval fish canned at the former ports were less than 181 mm. in length, such fish were omitted from the daily averages. As the data were smoothed by 29 calendar days, daily averages of fish taken in December affected the January averages for both the Monterey and San Pedro data. Because no pound ovals were taken at San Diego in December, all daily averages previous to January 10 and after April 10 were deleted from the San Pedro and Monterey data before the smoothed trends were calculated. Only data for 1928 and 1929 were used. The resultant two-season average trends for the three localities are shown in figure 8.

These trends indicate that the daily average lengths of San Diego fish more closely resemble the average lengths of Monterey sardines than of San Pedro. The maximum average size was not reached as

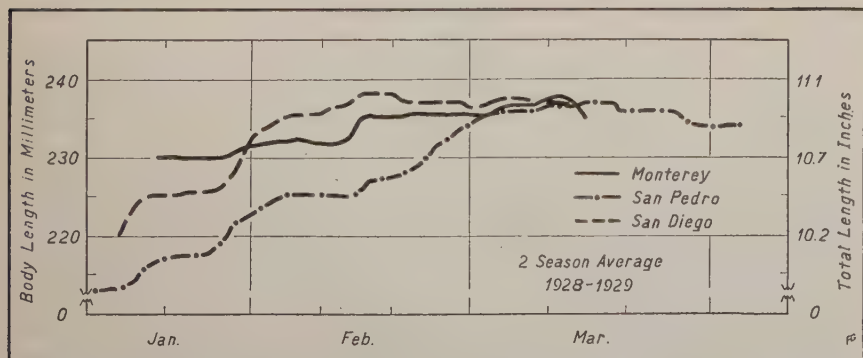


FIG. 8. Comparison of the two-season average trends of the daily average lengths of Monterey, San Pedro and San Diego sardines.

early at San Diego, however, as at Monterey and a slightly greater size eventually was attained. The maximum average size of the San Pedro fish for these two seasons was less than the Monterey maximum average, and the Monterey maximum was similarly somewhat less than the San Diego average. This closer correspondence between the Monterey and the San Diego average length trends than between the San Pedro and San Diego trends is surprising since the latter two fishing areas are separated by about one hundred miles, while the Monterey and San Diego regions are separated by approximately five hundred miles. Possibly studies over a longer period of time will furnish some explanation or demonstrate that the similarities between the Monterey and San Diego trends are merely apparent resulting from a comparison of too few data.

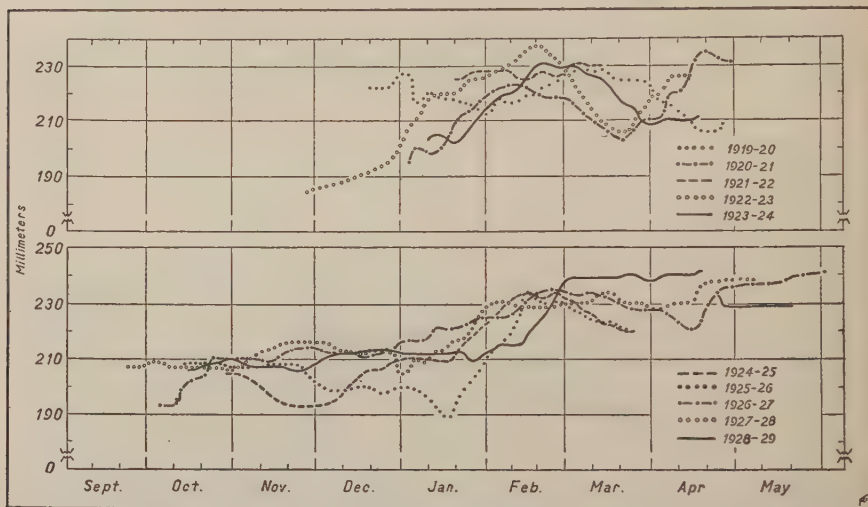


FIG. 9. Trends of the daily average lengths of San Pedro sardines for each season from 1919 to 1929.

SEASONAL DAILY AVERAGE LENGTH TRENDS FOR SAN PEDRO SARDINES

The ten-season average of daily average length trends and also the five-season average trends show the changes through which the sizes of sardines pass during a normal fishing season and demonstrate the similarities and differences between localities, but they obscure the variations from these averages which take place within any one fishing season. These variations become apparent in the daily average length trends for each season. Such trends are shown for San Diego in the previous section of this paper and were presented for Monterey by Seofield (1926.1) and Andrews (1928). Higgins (1926) discussed daily average lengths of San Pedro sardines for 1919-1923 but did not give average length trends. The trends for these four and the six succeeding seasons are shown in the two graphs of figure 9.

During the first five years of the 1919-1929 period (see the upper graph of fig. 9), the season extended from December or January to

the following April. For one season only, 1922-1923, were data available for the entire month of December. In the previous three years, fishing did not begin until late in December or early January. In the 1923-1924 season data were not collected until January although fishing had begun before this date. Since the dates on which changes in size occurred varied from season to season, the trends for these five seasons do not maintain a definite relationship to one another, but on the whole, certain changes in size occurred throughout each season. With the exception of the 1919-1920 season, the fish increased in size throughout January, reached a maximum in February, decreased during March, and increased again in April. In the 1919-1920 season, no definite minimum size was apparent and the maximum size was not reached until March and the decrease did not occur until April. The 1921-1922 fishing season was too brief to indicate anything but a maximum size. The average for this five-season period is shown in figure 5.

The trends of the daily average lengths for the following five seasons, 1924-1929, given in the lower graph of figure 9, indicate that the fishing seasons during this latter time interval were much longer than during the former. For three of the five seasons involved, fishing began in October and continued into May. This extension of the fishing season at San Pedro has resulted, probably not from a greater availability of the fish to the fishermen, but from a greater demand for fish. Sardines were undoubtedly present in the San Pedro fishing area during the fall months of the former years, but the demand for fish was not sufficiently great to pay the fishermen to search for the schools. Also in the 1924-1925 season, the purse seine was introduced into the San Pedro fishery. This net described by Scofield (1926.2) and Skogsberg (1925) is operated from a larger boat than is the lampara net on which, previous to this date, the sardine industry had depended. About 1927 the ring net, described by Fry (1930), was also introduced into the San Pedro fishery, but was used on both lampara and purse seine boats. The larger purse seine boats are run by diesel or black oil engines with a lower operation cost than the gasoline engines used on the smaller lampara boats. Because of this decrease in the cost of fuel, the purse seine boats cruise over a larger area in search of fish. The introduction of the purse seine was thus a contributory factor to the extension of the sardine season at San Pedro. This extension is most notable in the fall months of the 1924-1929 period, and as shown by Clark (1930), the major portion of the fall fishery is carried on farther from port than is the winter fishery.

As in the previous five seasons, during this second five-season interval, the changes in size and the time of the occurrence of these changes differed from season to season but the trends of the daily average lengths were similar in general slope throughout each season. From October to December, the fish were small, increased in size during January, reached a maximum in February, decreased slightly through March, and increased in April or May. The last three seasons, 1926-1929, reached a greater maximum than did the two former seasons, and showed very little drop in average lengths in March or April. In the 1928-1929 season, the maximum size was not attained until March and the decrease did not occur until late April and early May. The five-season average trend for this period is shown in figure 5.

During the ten fishing seasons for which data have been collected, the trends of the daily average lengths have passed through the same changes, from small average sizes in the fall months to larger averages in the winter with a slight decrease at the close of the fishing season. However, the dates during which these changes in average lengths occurred varied from season to season. The fish of the 1920-1921 and the 1927-1928 seasons reached a maximum by the first of February, while in 1919-1920 and 1928-1929, the maximum average size was not attained until the first of March. In other seasons a maximum was attained at some point between these two dates. Similarly, the origin of the slight drop in average sizes in the spring occurred between the first of March and the first of April, except in 1928-1929 when the average lengths did not begin to decrease until the first of May. This drop was less conspicuous during the last three seasons than in former years, but whether this is a chance variation or whether it will persist in future years can not be foretold. The explanation of this variation

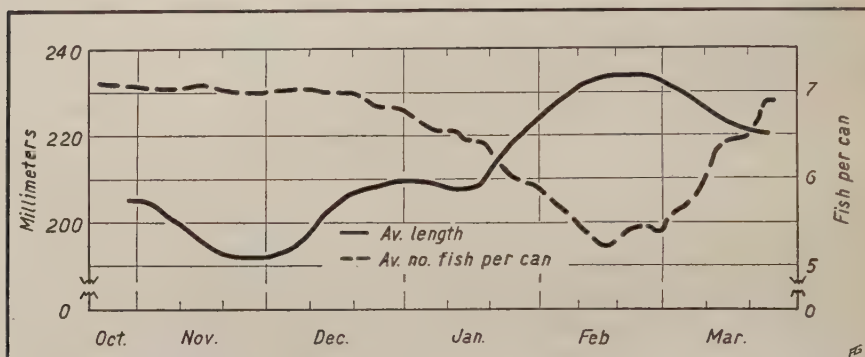


FIG. 10. Correlation between the trends of the daily average lengths and the daily average number of fish packed in a pound-oval can for the 1924-1925 season for San Pedro sardines.

from season to season of the dates during which the changes in average length trends occurred is not apparent from the data at hand. The variations may be dependent upon one or many factors, such as food, temperature, salinity, or currents.

RELATION BETWEEN LENGTH OF FISH AND THE NUMBER OF FISH PACKED PER CAN

Seasonal Relation.

As mentioned in the introduction, changes in the size of fish throughout a season directly affect the sardine pack. When small fish are taken in abundance more fish are packed in a can than when large fish predominate. To indicate this relationship, records of the number of fish packed per pound-oval can were secured through the courtesy of two canning companies at San Pedro and two at Monterey.

In the earlier years the trade demanded a careful segregation of the pack according to the number of fish per can. This was an expensive process and has not been carried out with much exactness in the later years. For this reason the cannery records are more reliable for the former than the last two or three seasons. Also by cutting off a larger

portion of the fish, more large fish are packed in a can than if the heads are removed by cutting just behind the pectoral fins as is done with the smaller fish. By this process many fish that would ordinarily be canned five to the can are packed under the category of "six-eighths." The close relationship between the average size of the fish and the number of fish per can is therefore more significant since the inaccuracies of the cannery records tend to minimize rather than to increase this relationship.

These records, covering seven seasons at San Pedro and eight at Monterey, showed a seasonal fluctuation in the average number of fish

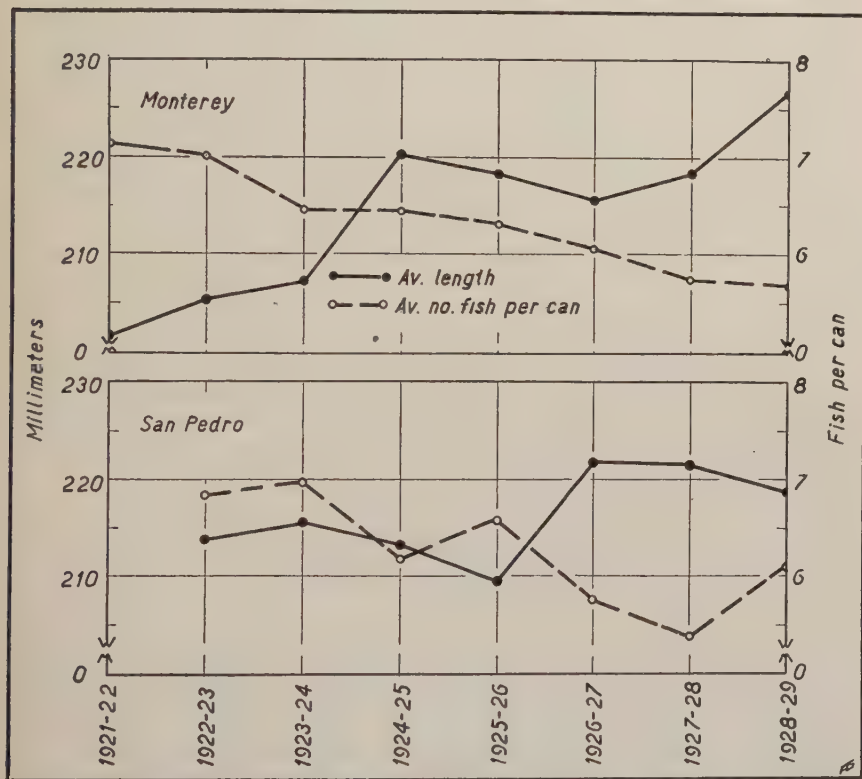


FIG. 11. Correlation between the seasonal average lengths and the seasonal average number of fish packed in a pound-oval can for Monterey and for San Pedro sardines.

packed per can which followed very closely the seasonal changes in the daily average length of the sardines. When small fish were most numerous in the catch, more fish were packed in each can and when large fish predominated fewer fish were put in each can. Figure 10, which represents data for the 1924-1925 season at San Pedro, shows clearly this inverse correlation between size of fish and number packed in a can. The data for each of these curves were treated in the same manner: The daily average lengths and the daily average number of fish per can were both smoothed by a moving average of 29 calendar days. In November and most of December when the fish were small,

approximately seven fish were packed per can; in late December and January, as the fish increased in average length the number per can decreased, reaching a minimum in the middle of February. This minimum corresponded to the maximum average lengths attained in the same month. The decrease in average length of the sardines during March was accompanied by an increase in the average number of fish packed per can.

Correlation from Season to Season.

The decided inverse correlation evinced throughout each season between the *daily* average lengths and the *daily* average number of fish packed per can was scarcely greater than the negative correlation between the *seasonal* average length of the sardines and the *seasonal* average number of fish per can. These data are shown for San Pedro and for Monterey in figure 11. In the later seasons when sardines averaged larger, the number of fish in each can averaged smaller. This increase in the seasonal average lengths corresponded to the increase in the daily average length trends as shown by the comparison between the 1919-1924 and the 1924-1929 periods. (See fig. 5.)

The coefficients of correlation² as calculated for the data of figure 11 are:

$$\begin{array}{ll} \text{San Pedro} & r = -0.80 \quad PE_r \pm 0.09 \\ \text{Monterey} & r = -0.79 \quad PE_r \pm 0.09 \end{array}$$

These very high negative correlation coefficients indicate a close dependence of the type of the sardine pack on the size of sardines caught. Cannerymen can not plan to pack the same number of fish in a can throughout the entire season nor from season to season. As the sardines fluctuate in size so fluctuates the nature of the pack.

POSSIBLE EXPLANATIONS OF THE CHANGES IN DAILY AVERAGE LENGTHS

Variations Between Seasons and Localities.

The comparison of the five-season daily average length trend for the 1919-1924 period with the similar trend for the 1924-1929 interval for both the Monterey and San Pedro regions (see fig. 5) indicated that with the exception of the transition period in January, the daily averages were greater for the latter five years. An explanation of this is probably dependent on dominant size classes. Unpublished data dealing with the number of fish at each length unit indicate that in both localities dominant year classes have been reaching a maximum size during the second five-year interval, and the data suggest a lack of younger and smaller year groups. This possible dependence of the fishery on older and larger year classes necessarily would result in an increase in daily average lengths. A comprehensive understanding of the effect of dominant size classes on the commercial catch of sardines must await further analysis of the length frequency data accumulated by the California State Fisheries Laboratory. This phase of the work was covered by Thompson (1926), Higgins (1926) and Scofield (1926.1)

$$^2 \quad r = \frac{\sum xy}{N \sigma_x \sigma_y} \quad PE_r = 0.6745 \frac{1-r^2}{\sqrt{N}}$$

for the years 1919 to 1923, and the later seasons are now being subjected to an intensive study, the results of which should be published in the near future.

Reasons for the greater average sizes during October, November and December at Monterey than at San Pedro are not apparent as yet. Although the trends from the two localities are not compared for individual seasons, these differences, with a few minor exceptions, were manifest throughout the entire ten years and thus can not be explained by the presence of dominant classes of older fish during the last five seasons. Furthermore such dominant groups were present in both fisheries. Racial segregation might account for the variations, but the studies by Hubbs (1925) and further unpublished work of the California State Fisheries Laboratory have not demonstrated significant racial differences between fish from the two localities. A gradual northward drift of larger fish has been suggested, and if this were true, might account for the greater daily average sizes at Monterey, but would not explain the greater averages at San Diego, since the latter port lies south of San Pedro. More knowledge concerning the movements of the California sardine must be acquired before such movements can be accepted as a reason for size differences between fish from the three fishing localities.

In a discussion of several possible explanations of size differences between sardines from northern and southern localities, Thompson (1921) advanced the theory that in the southern waters spawning may be more successful than in the more northern waters, but due to the presence of more numerous and active enemies, fewer fish would reach a large size. This would result in a preponderance of smaller, younger fish in the southern fishing areas. On the other hand in the northern localities spawning may be less successful but the chances of survival, because of fewer enemies, may be greater, resulting in a preponderance of larger, older fish. However, this theory also fails to account for the larger daily average size of pound-oval fish at San Diego to the south of San Pedro.

Fluctuations Within a Season.

The reasons for the seasonal fluctuations in the daily average lengths are, however, slightly more evident. Andrews (1928) discussed possible causes of these seasonal fluctuations at Monterey. His conclusions are equally applicable to the data for the other ports. Obviously the increase in size throughout a fishing season can not be explained by growth, since the large size range indicated that several year classes were involved, thus obscuring any growth phenomenon, and the decrease in average size in the spring would not have occurred if the winter increase were dependent on growth. Selection on the part of the fishermen of certain sizes at different times in a fishing season is not probable for a demand for such selection is not apparent in the industry. No differential gear selection has been demonstrated in the sardine fishery. The fish are caught in purse seine, ring and lampara nets, but no evidence is at hand to indicate that these three types of nets take different sizes of fish. Moreover, during the ten years covered by this study, sardines at Monterey were taken almost exclusively by lampara nets, while for the first five years at San Pedro fishing was carried on by lampara nets, and for the last five years by purse seines,

lampara and ring nets. In both districts the same fluctuations in average lengths occurred throughout each season, regardless of the gear used.

Neither can the hypothesis be substantiated that different sized fish are caught in different localities of each fishing region, and that fishermen operate in these localities at different times in a fishing season. For San Pedro, Clark (1930) showed that fall fish were caught chiefly around the Channel Islands and winter fish off the mainland. This might suggest that smaller fish were taken around the islands and larger fish off the mainland; however, during the 1922-1923 and the 1924-1925 seasons when fall fishing took place off the mainland only, the small sizes were taken in the fall months and larger sizes in the winter months as in the other seasons. In the last three seasons, 1926-1929, during the winter months a continually increasing percentage of fish were taken from around the islands, but the maximum average lengths for these three seasons were as great or greater than for any other season. Also, Lindner (1930) showed that the Monterey fishing area was approximately the same for both the fall and winter months of the past ten years, and yet the daily average lengths at Monterey passed through the same seasonal changes as did the San Pedro averages. Selection of certain fishing grounds can not account, therefore, for these average length fluctuations.

The only explanation which satisfies all conditions is the movement into the fishing areas at different times in the season of certain sized sardines. In the fall months the smaller fish appear in the fishing localities, and as the season advances an influx of larger fish takes place which raises the average lengths to a maximum in the winter months. In the spring months the larger fish may move out of the fishing area earlier than do the smaller fish which possibly accounts for the slight decrease in average sizes at this time.

For the San Pedro region at least, and probably also for Monterey, the coming into the fishing area of the larger fish does not indicate a disappearance of the smaller fish, but their presence in the commercial catch is masked by the greater abundance of larger fish. This fact is indicated by unpublished data collected by the California State Fisheries Laboratory. Data are too scanty to permit the drawing of conclusions about the movements of sardines in the San Diego locality.

The causes of these movements of the California sardine are probably many and varied. Undoubtedly spawning plays an important role.³ An understanding of other contributory factors involves detailed oceanographic studies over large areas and many years, but until such information is available and before it can be applied to the problem of the movements of the sardine, a more comprehensive conception of these movements must be attained.

³ This phase of the sardine population studies is now being subjected to an intensive investigation and gives promise of fruitful results.

SUMMARY

Throughout a fishing season the daily average lengths of the California sardine were small during the fall months, increased to a maximum in the winter months and decreased slightly in the spring. The dates of this transition from smaller to larger fish differed by a month between Monterey and San Pedro.

For the ten seasons studied, 1919-1929, the daily average lengths in the five-season average trends were greater during the last five years than during the first five. This increase probably resulted from the presence in the catch of dominant size groups which reached a maximum size during the latter period.

The daily average lengths were greater for the Monterey fall fish than for the San Pedro fall fish, and the winter averages for San Diego more nearly approximated those for Monterey than those for San Pedro. No explanation for these differences in averages between localities was evident.

The only satisfactory explanation of the seasonal fluctuations in daily average lengths at each locality is the movement of different sized fish in to and out of the fishing area. The cause of these movements can only be surmised.

The changes in daily average length showed a marked negative correlation with the average number of fish packed in a pound-oval can. This inverse correlation was evident between daily averages and between seasonal averages.

LITERATURE CITED

Andrews, Carroll B.

1928. Seasonal average length trends at Monterey of the California sardine (*Sardina caerulea*). California Division of Fish and Game, Fish Bulletin No. 13, p. 1-12.

Clark, Frances N.

1930. Fishing localities off San Pedro from 1919 to 1929 for the California sardine, *Sardina caerulea*. California Division of Fish and Game, Fish Bulletin No. 25, p. 28-39.

Fry, Donald H., Jr.

1930. The ring net, half ring net, or purse lampara in California Fisheries. California Division of Fish and Game, Fish Bulletin No. 27.

Higgins, Elmer.

1926. A study of fluctuations in the sardine fishery at San Pedro. California Fish and Game Commission, Fish Bulletin No. 11, p. 125-158.

Hubbs, Carl L.

1925. Racial and seasonal variation in the Pacific herring, California sardine and California anchovy. California Fish and Game Commission, Fish Bulletin No. 8, p. 1-23.

Lindner, Milton J.

1930. Fishing localities at Monterey from November, 1919, to March, 1929, for the California sardine, *Sardina caerulea*. California Division of Fish and Game, Fish Bulletin No. 25, p. 8-27.

Scofield, W. L.

- 1926.1. The sardine at Monterey: Dominant size-classes and their progression, 1919-1923. California Fish and Game Commission, Fish Bulletin No. 11, p. 191-221.
1926.2. Purse seines for California sardines. California Fish and Game, Vol. 12, No. 1, p. 16-19.
1928. Sardine seasons at Monterey and Los Angeles Harbor. California Fish and Game, Vol. 14, No. 3, p. 198-200.

Sette, Oscar Elton.

1926. Sampling the California sardine: A study of the adequacy of various systems at Monterey. California Fish and Game Commission, Fish Bulletin No. 11, p. 67-123.

Skogsberg, Tage.

1925. Preliminary investigation of the purse seine industry of Southern California. California Fish and Game Commission, Fish Bulletin No. 9, p. 88-95.

Thompson, W. F.

1921. Quarter-oils or half-pound ovals. California Fish and Game, Vol. 7, No. 2, p. 106-110.
1926. Errors in method of sampling used in the study of the California sardine. California Fish and Game Commission, Fish Bulletin No. 11, p. 159-189.

CALIFORNIA DIVISION OF FISH AND GAME
FISH BULLETINS

- * No. 1. Report on Fish Conditions, 1913; 48 pp., 3 figs. Contains:
The Abalone Industry in California. By Charles Lincoln Edwards.
The Towing of Salmon and Steelhead Fry from Sacramento to the Sea
in a "Live Car." By N. B. Scofield.
The Problem of the Spiny Lobster. By Bennet M. Allen.
Investigation of the Clams of California. By Harold Heath.
Investigation of the Life History of the Edible Crab (*Cancer magister*).
By F. W. Weymouth.
A General Report on a Quinnat Salmon Investigation carried on during
the Spring and Summer of 1911. By N. B. Scofield.
Trout and Black Bass Planting and Transplanting in the San Joaquin
and Southern Sierra Districts. By A. D. Ferguson.
- * No. 2. The Scientific Investigation of Marine Fisheries as Related to the Work
of the Fish and Game Commission in Southern California. By Will F.
Thompson. 1919; 27 pp., 4 figs.
- * No. 3. The Spawning of the Grunion (*Leuresthes tenuis*). By Will F. Thomp-
son, assisted by Julia Bell Thompson. July 15, 1919; 29 pp., 9 figs.
- No. 4. The Edible Clams, Mussels and Scallops of California. By Frank W.
Weymouth. Jan. 10, 1921; 74 pp., 19 pls., 26 figs.
- * No. 5. A Key to the Families of Marine Fishes of the West Coast. By Edwin
C. Starks. March 3, 1921; 16 pp., 4 figs.
- * No. 6. A History of California Shore Whaling. By Edwin C. Starks. October,
1922; 38 pp., 22 figs.
- * No. 7. The Life History and Growth of the Pismo Clam. By Frank W. Wey-
mouth. 1923; 120 pp., 15 figs., 18 graphs.
- * No. 8. Racial and Seasonal Variation in the Pacific Herring, California Sardine
and California Anchovy. By Carl L. Hubbs. February, 1925; 23 pp.,
4 pls.
- * No. 9. Preliminary Investigation of the Purse Seine Industry of Southern Cali-
fornia. By Tage Skogsberg. 1925; 95 pp., 23 figs.
- * No. 10. The Life History of *Leuresthes tenuis*, an Atherine Fish With Tide-
Controlled Spawning Habits. By Frances N. Clark. October, 1925; 51
pp., 6 graphs, 7 pls.
- No. 11. The California Sardine. By the Staff of the California State Fisheries
Laboratory. 1926; 221 pp., 74 figs.
I. Thompson, Will F. The California Sardine and the Study of the
Available Supply.
II. Sette, Oscar Elton. Sampling the California Sardine: A Study
of the Adequacy of Various Systems at Monterey.
III. Higgins, Elmer H. A Study of Fluctuations in the Sardine
Fishery at San Pedro.
IV. Thompson, Will F. Errors in the Method of Sampling Used in
the Study of the California Sardine.
V. Scofield, W. L. The Sardine at Monterey: Dominant Size
Classes and their Progression, 1919-1923.
- No. 12. The Weight-Length Relationship of the California Sardine (*Sardina
caerulea*) at San Pedro. By Frances N. Clark. 1928; 58 pp., 11 figs.
- No. 13. The Seasonal Average Length Trends at Monterey of the California
Sardine (*Sardina caerulea*). By Carroll B. Andrews. 1928; 13 pp.,
6 figs.
- No. 14. Report on the Seals and Sea Lions of California. By Paul Bonnot.
1928; 61 pp., 38 figs.
- No. 15. The Commercial Fish Catch of California for the Years 1926 and 1927.
By the Bureau of Commercial Fisheries. 1929; 94 pp., 52 figs.
- No. 16. The Life History of the California Jack Smelt, *Atherinopsis californi-
ensis*. By Frances N. Clark. 1929; 22 pp., 12 figs.
- No. 17. Sacramento-San Joaquin Salmon (*Oncorhynchus tshawytscha*) Fishery
of California. By G. H. Clark. 1929; 73 pp., 32 figs.
- No. 18. The Pismo Clam. Further Studies of its Life-History and Depletion.
By William C. Herrington. 1930; 67 pp., 16 figs.
- No. 19. Sardine Fishing Methods at Monterey, California. By W. L. Scofield.
1929; 61 pp., 27 figs.

- No. 20. The Commercial Fish Catch of California for the Year 1928. By the Staff of the Bureau of Commercial Fisheries. 1930; 109 pp., 62 figs.
- No. 21. Analysis of Boat Catches of White Sea Bass (*Cynoscion nobilis*) at San Pedro, California. By S. S. Whitehead. 1930; 26 pp., 20 figs.
- No. 22. A Bibliography of the Tunas. By Genevieve Corwin. 1930; 103 pp.
- No. 23. Success of the Purse Seine Boat in the Sardine Fishery at Monterey, California. (1929-1930 Fishing Season.) By J. B. Phillips. 1930.
- No. 24. An Analysis of the Catch Statistics of the Striped Bass (*Roccus lineatus*) Fishery of California. By J. A. Craig. 1930; 41 pp., 22 figs.
- No. 25. Fishing Areas Along the California Coast for the Sardine (*Sardina caerulea*). By the California State Fisheries Laboratory. 1930. 44 pp., 25 figs.
- No. 26. Seasonal Changes in the Daily Average Length of the California Sardine (*Sardina caerulea*). By Frances N. Clark. 1930; 22 pp., 11 figs.

These bulletins are offered free of charge to interested persons and in exchange for the publications of other bodies engaged in marine research. Address: California State Fisheries Laboratory, Terminal Island, California.

LIBRARY
BUREAU OF COMMERCIAL FISHERIES
U. S. FISH AND WILDLIFE SERVICE
P. O. BOX 3830
HONOLULU 12, HAWAII